

UNIT-3

SPILL WAYS

When the water in the reservoir increases, the large accumulation of water endangers the stability of the dam structure. To avoid this, a structure is provided in the body of a dam or near the dam or periphery of the reservoir. This structure is called as spillway. Spillway is a passageway through which surplus water escapes from a reservoir, lake, or the like.

Functions of spillway

- Mainly used to discharge water during flood period.
- Provide structural stability to the dam under all condition
- Should able to pass the designed flood without raising the reservoir level above H.F.L.
- Should have an efficient operation
- Should be economical
- Safe disposal of water without toe erosion

Location of Spillway

1. Spillways may be provided within the body of the dam
2. Spillways may sometimes be provided at one side or both sides of the dam
3. Sometimes by-pass spillway is provided which is completely separate from the dam

Component parts of Spillway:

1. Approach channel
2. Control structure
3. Discharge carrier

4. Discharge channel
5. Energy dissipater's.

(1) Approach channel

- Entrance structure or the path to draw water from reservoir and convey it to the control structure.
- It may be straight or curved in plan.
- Its banks may be parallel, convergent, divergent or combination of these and may be vertical or sloping.
- It may insure minimum head loss through the channel and to obtain uniformity of flow over the control structure.

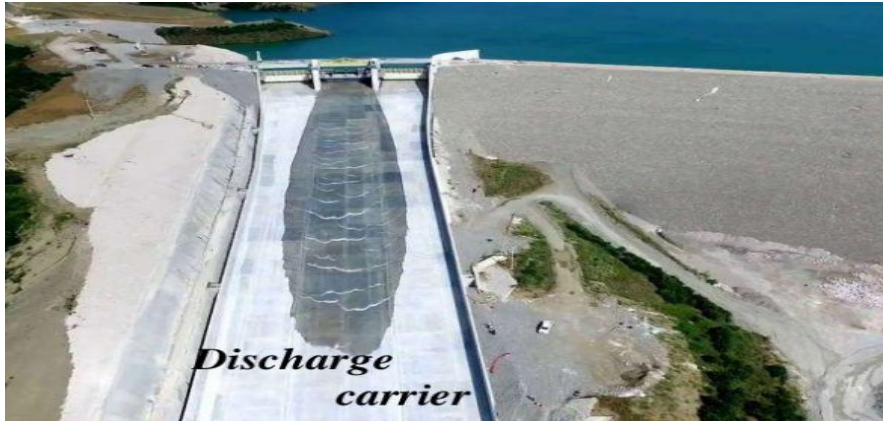
(2) Control structure

- Major component of spillway provided with bridge and gates.
- Regulates and controls the surplus water from the reservoir.
- It does not allow discharge of water below the fixed reservoir level.



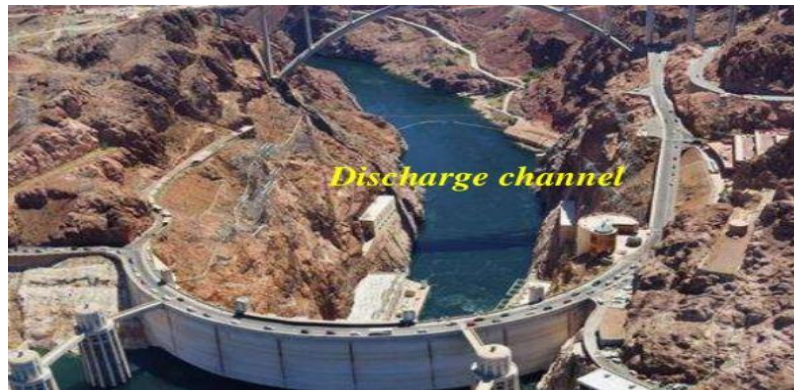
(3) Discharge carrier

- It is the waterway provided to convey the flows released from the control structure to the downstream side of spillway.
- The cross section may be rectangular, trapezoidal or of other shape.
- Waterway may be wide or narrow, long or short.



(4) Discharge channel

- Provided to convey the water from bottom of the discharge carrier to the downstream flowing river.
- It may be the downstream face of spillway itself.
- The width of discharge channel depends on amount of water to be conveyed.



(5) Energy dissipators

- At the end of discharge carrier, the water released from control structure has great velocities enough to cause scour.
- Thus, energy dissipators are provided to avoid the scouring of downstream side of spillway.
- These are to be provided before water entering the discharge channel.

The following are the different types of dissipators:

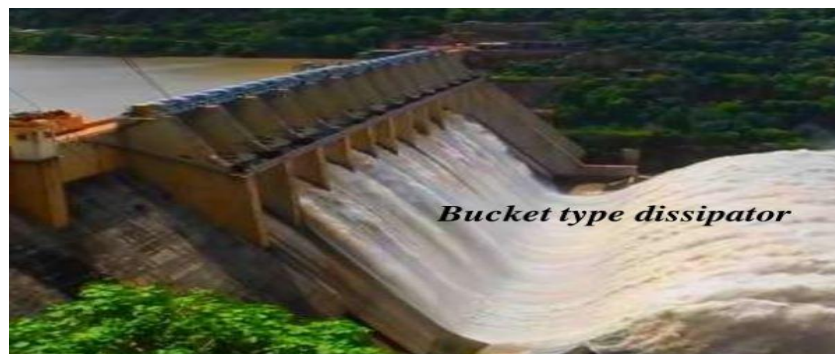
- i. Bucket type energy dissipators
- ii. Stilling basin type dissipators
- iii. Baffle type dissipators.

(i) Bucket type dissipators

a. Roller bucket type

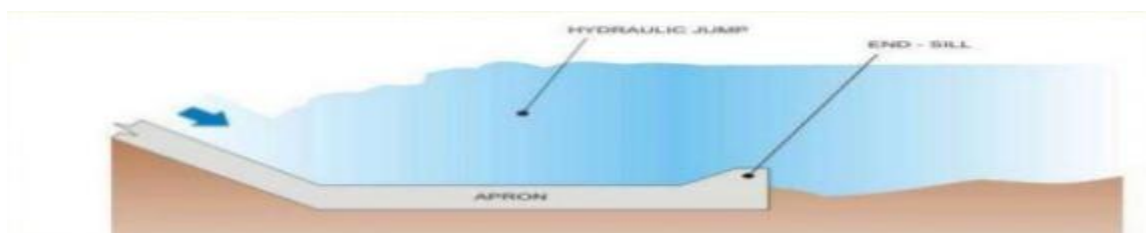
b. Ski jump bucket type

- The high kinetic energy of water is reduced by providing a hydraulic jump at the end of spillway.
- The hydraulic jump can be achieved by providing bucket type dissipators.
- By hydraulic jump of water some part of energy is dissipated by aeration.

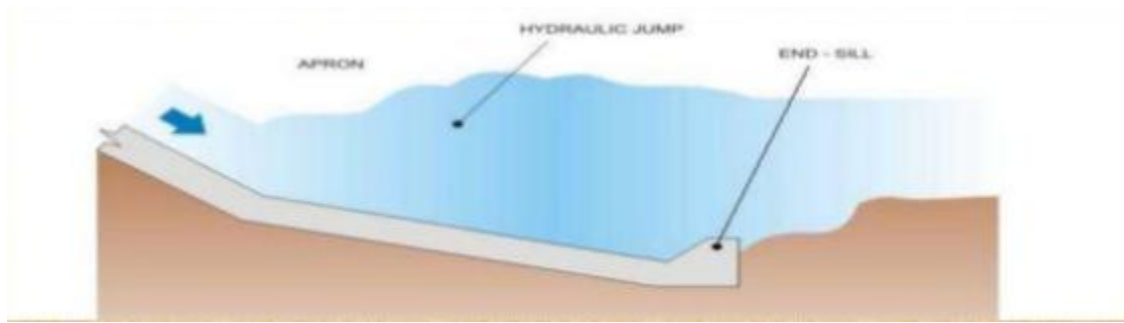


(ii) Stilling basin

a. Horizontal apron type



b. Sloping apron type



- Stilling basins are usually provided after the buckets.
- Due to the hydraulic jump of water, the water falling on the ground may cause cavitations on the ground.
- These cavitations can be avoided by providing the stilling basin.
- The stilling basin consists of water which reduces some part of energy of water.

(iii) Baffle type dissipators

- After passing the stilling basin water has still some energy.
- If any amount of energy exists, it can be fully dissipated by providing baffle dissipators.
- In this, baffle type structures are provided in a number of series depending on the amount of energy.



TYPES OF SPILLWAYS

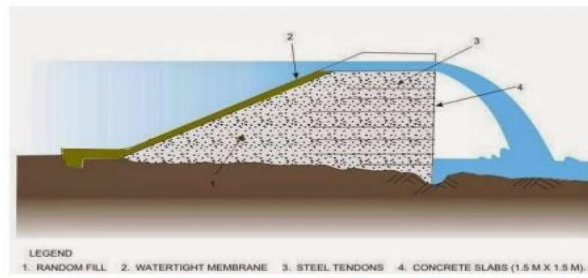
(1) Main spillway

- i. Free Over-fall spillway
- ii. Over-flow spillway
- iii. Chute spillway
- iv. Saddle spillway
- v. Shaft spillway
- vi. Side channel spillway
- vii. siphon spillway

(2) Emergency spillway

(i) Free over fall spillways or Straight drop Spillway

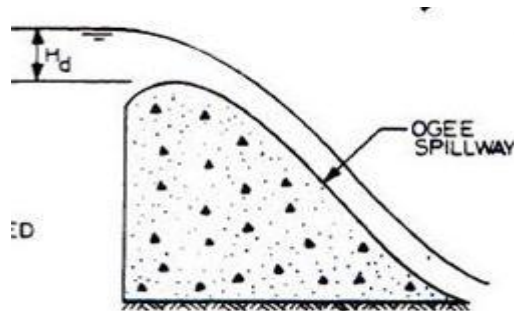
- In this type of spillway, the water freely drops down from the crest.
- It is a low weir and simple vertical fall type structures.
- The water falls freely from the crest under the action of gravity.
- To prevent scouring at the downstream, an auxiliary dam or artificial pool is to be constructed at the place of fall of water.
- Straight drop spillway is suitable for arch dams and for small drops
- Usually appropriate for thin dams having almost vertical downstream faces.
- This type of spillways may be economical for low heads as compared with overflow spillways because of saving in concrete.
- Not recommended for high heads because of structural instability problems.



Free Overfall or Straight Drop Spillway

(ii) Overflow spillway or ogee spillway

- It represents the S-shape curve so, it is called ogee spillway.
- It is an improved form of straight drop spillway.
- It is mainly used in gravity dams.
- It has got the advantage over other spillways for its high discharging efficiency.
- widely used on gravity, arch, & buttress dam



(iii) Shaft spillway or morning glory spillway

- The water from the reservoir enters into a vertical shaft which conveys this water into a horizontal tunnel which finally discharges the water into the river downstream.
- This type of spillway is preferred where the space is not available for providing the above type of spillways
- If the inlet leg is provided in shape of a funnel, it is called Morning Glory Spillway.
- It has maximum discharge even at low heads.

- This type of spillway is not suitable for large capacity and deep reservoirs because of stability problems.
- Special designs are required to handle cavitation damage at the transition between shaft and tunnel.
- Repair and maintenance of shaft spillways are difficult.



(iv) Siphon spillway

- It works on the principle of syphonic action.
- It consists of a syphon pipe whose inlet leg is kept just below the normal pool level and an air vent kept at normal pool level is connected to the crown of syphon.
- When the water raises the pool level, syphonic action starts automatically and the water discharges to downstream side.
- When the water level falls below the pool level, air is entered through air vent and the discharging of water stops.
- The flow would result excessive vibrations in the dam body which may cause expansion problems in the joints.
- There is a possibility of cavitation for negative pressures, which is affected by the head between upstream and downstream water levels.
- Repair and maintenance of siphon spillways are difficult.
- It has a limited capacity.



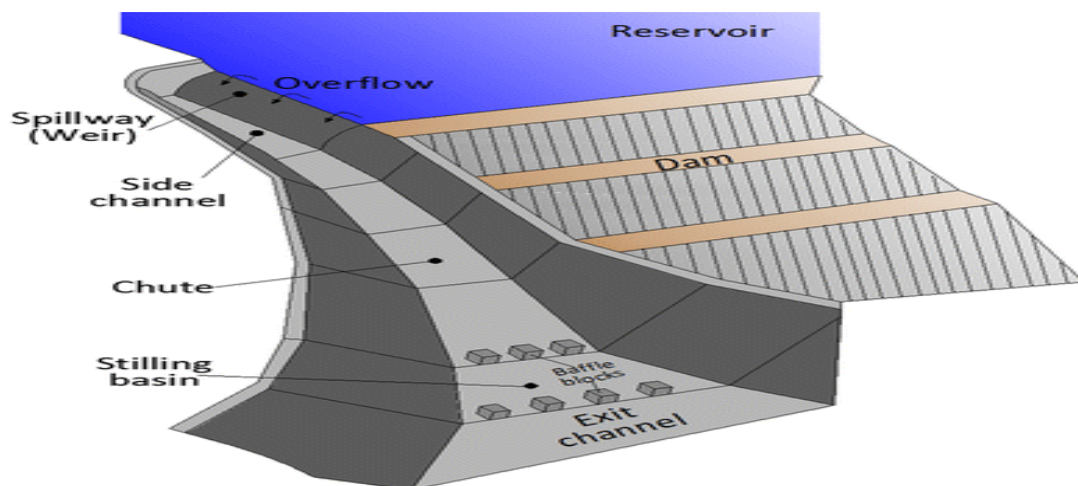
(v) Chute spillway or trough or open channel spillway

- In this type water is conveyed from the reservoir to the river or to nalla below the dam through an excavated open channel, through fairly steep slope.
- Chute spillways are used in flow ways where water is to be lowered from one level to another and where it is desirable to avoid a stilling basin.
- For earthen and rock fill dams, spillway is to be constructed separately away from the main valley. Chute Spillway is the simplest type of a spillway which can be easily provided independently and at low costs.
- It is lighter and adaptable to any type of foundations.
- However this type of spillway should not be provided where too many bends are to be given as per topography.



(vi) Side channel spillway

- When the dam is not rigid and it is undesirable to pass flood water over the dam, this type of spillway is used.
- The flow in this spillway is turned 90° after passing the crest such that the flow is parallel to the weir crest.
- It is preferred where space is not available for providing sufficient crest width for chute spillway.
- The discharge carrier may be an open channel type or a conduit type.
- Discharge characteristics of a side channel spillway are similar to those of an ordinary overflow spillway and are dependent on the selected profile of the weir crest.
- Although the side channel is not hydraulically efficient, nor inexpensive, it has advantages which make it adoptable to spillways where a long overflow crest is required in order to limit the afflux (surcharge held to cause flow) and the abutments are steep.



(vii) Saddle spillway

- This type is mainly used when other types are not favourable.
- In some basins formed by a dam, there may be one or more natural depressions or saddles in the rim of the basin, which can be used as spillway.

- It is essential that the bottom of the depression should be at full reservoir level. It is usually necessary for the saddle to be on firm rock.

(viii) Conduit or Tunnel Spillway

- Where a closed channel is used to convey the discharge around a dam through the adjoining hill sides, the spillway is often called a tunnel or conduit spillway.
- The closed channel may take the form of a vertical or inclined shaft, a horizontal tunnel through earth or rock, or a conduit constructed in open cut and backfilled with earth materials.
- Tunnel spillways are advantageous for dam sites in narrow gorges with steep abutments or at sites where there is danger to open channels from rock slides from the hills adjoining the reservoir.

EMERGENCY SPILLWAY

- This type is rarely used.
- Extra spillways provided on a project in rare case of extreme floods (emergency)
- Used to convey frequently occurring outflow rate.

TYPES OF GATES

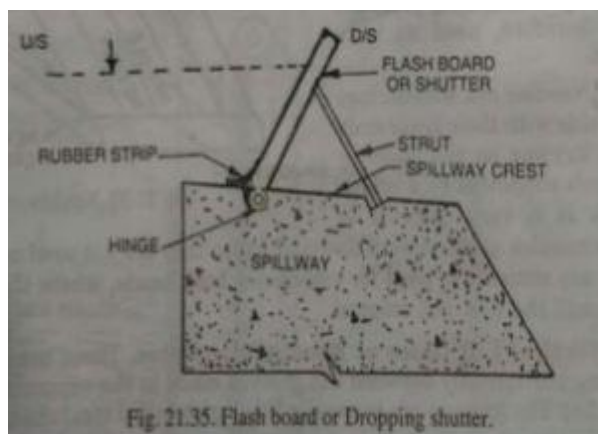
- Spillway gate, also called stop gates, are adjustable gates used to control water flow in reservoir, river, stream systems.
- They also acts as barrier for the storage of additional water.
- By these the height of the dam will be more such that land acquisition will be more.
- Gates can be provided to all types of spillways except siphon spillway , because the raise in flood level is already small compared to the other types of spillways spillway crest gates

Types of spillway gates

1. dripping shutters or permanent flash boards
2. stop logs and needles
3. radial gate or tainter gates
4. drum gates
5. vertical lift gates or rectangle gates

Dripping shutters or permanent flash boards

- consists of wooden panels of usually 1.0-1.25m high
- Hinged at bottom and are supported against water pressure by struts. the shutters falls flat on the crest when the downstream supporting struts are tripped. Hence they are not suitable for curved crests.
- These shutters can be raised or lowered from an over-head cableway or a bridge. Various automatic gates which drop themselves have been designed these days.



Stop logs and needles stop logs

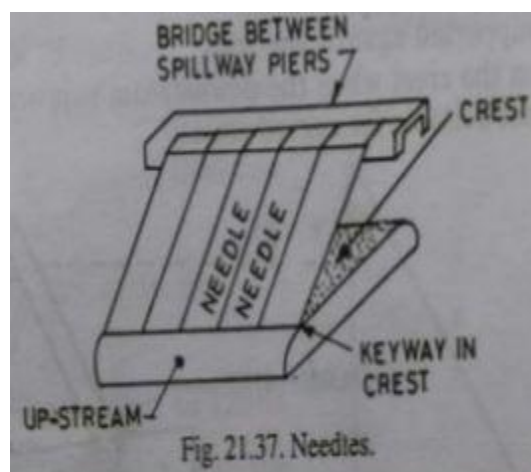
- They consists of wooden beams or planks placed one upon the other and spanning in the grooves b/w the spillway piers .
- They can be removed either by hand or with hoisting mechanism.
- It takes lot of time for removing them, if they become jammed in slots.

- Leakage b/w logs is a big problem hence they are used in minor works.



Needles

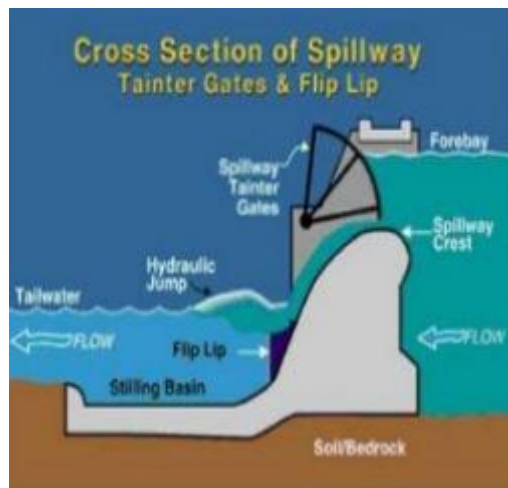
- Needles are wooden logs kept side by side with their lower ends resting in a keyway on the spillway and upper ends supported by a bridge girder.
- It is difficult to handle these at the time of flow hence these are not used on any major works.
- They are sometimes used for emergency bulk heads, where they need not be replaced until the flow has stopped.



Radial gate or tainter gates

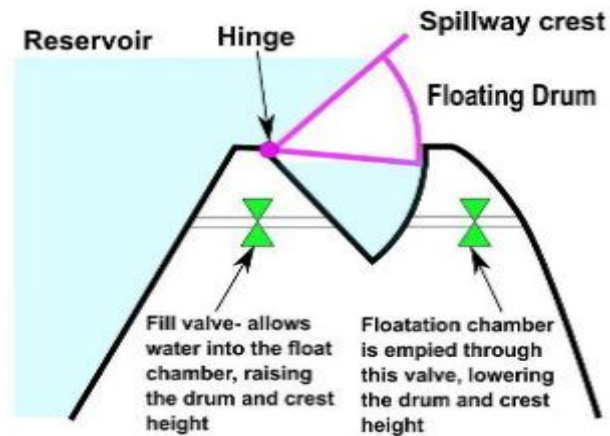
- Radial gates are rotary gates consisting of cylindrical sections.

- They may rotate vertically or horizontally.
- Tainter gates are a vertical design that rotates up to allow water to pass underneath.
- Low friction trunnion bearings, along with a face shape that balances hydrostatic forces, allow this design to close under its own weight as a safety feature.



Drum gates

- Drum gates are hollow gate sections that float on water.
- They are pinned to rotate up or down. Water is allowed into or out of the flotation chamber to adjust the dam's crest height.
- These are desirable to longer spans in order of 40 or so and medium heights of 10 or so.

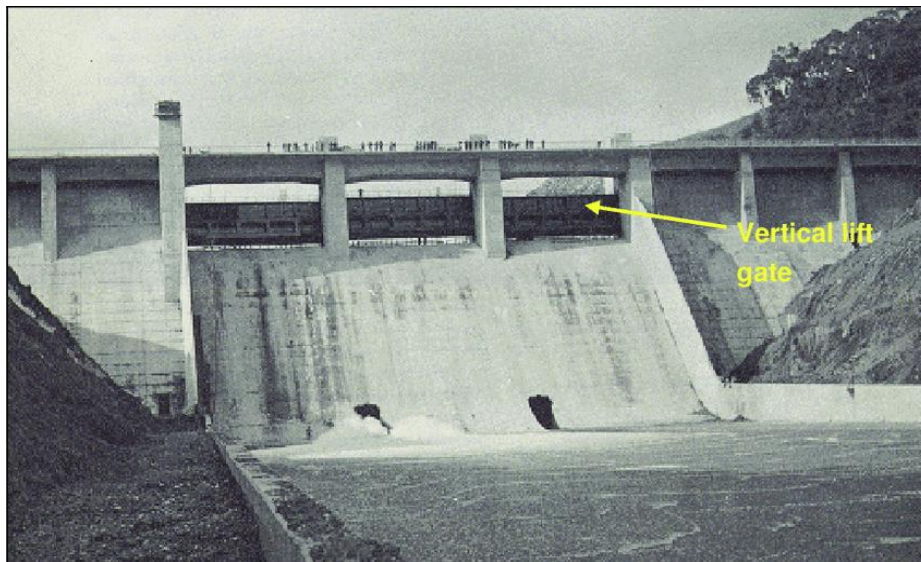
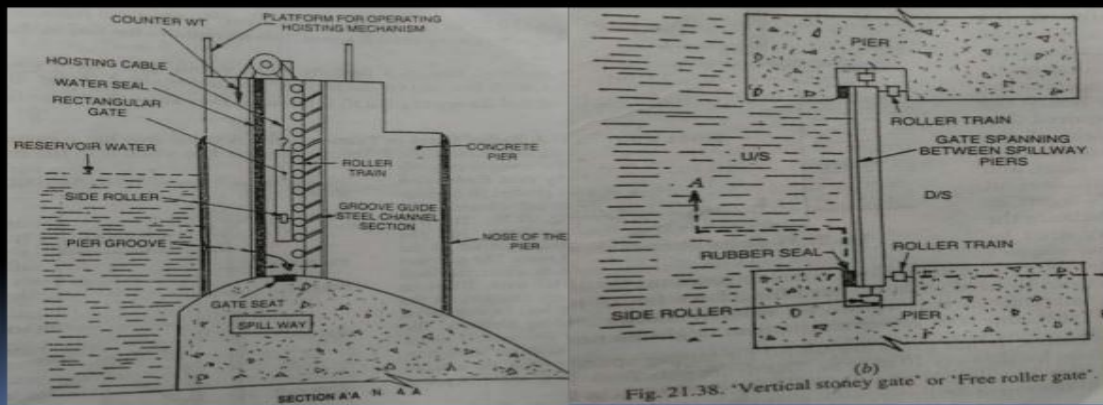


Vertical lift gates or rectangle gates

- Rectangular gates are spinning horizontally b/w the grooves made in the supporting spillway piers.
- The grooves are lined with rolled steel channel sections of appropriate size, so as to provide smooth bearing surface having sufficient bearing strength and are known as groove guides.
- Rectangular gates move b/w groove guides, and can be raised or lowered by a hoisting mechanism at the top.
- The gates are made of steel or concrete or wood.
- The frictional resistance b/w gate and downstream groove guide can be reduced by placing cylindrical rollers b/w the bearing surface of the gate and the guide grooves.
- Large verticals lift gates may be counter balanced by a counterweight beam, which is loaded to balance self weight of the gate, so hoisting force is required to balance the frictional resistance.

The sectional view and plan of vertical lift gate

THE SECTIONAL VIEW AND PLAN OF VERTICAL LIFT GATE



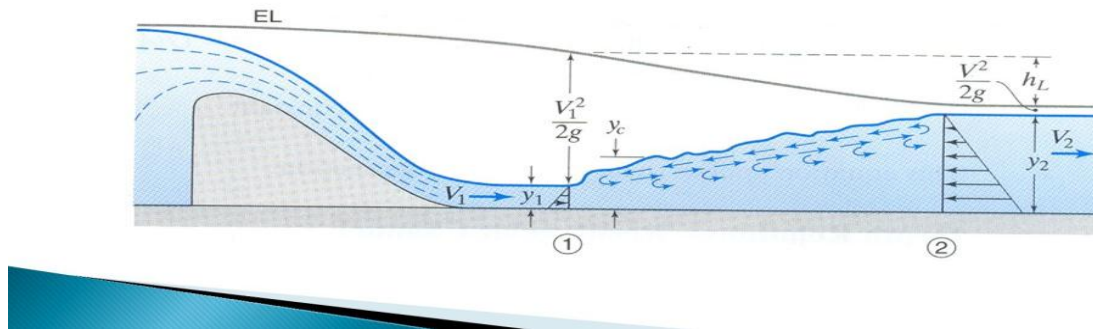
ENERGY DISSIPATION BELOW SPILLWAY

- Water flowing over a spillway acquires a lot of kinetic energy because of the conversion of the potential energy into kinetic energy.
- If the water flowing with such a high velocity is discharged into river it will scour the river bed.
- If the scour is not properly controlled, it may extend backward and may endanger the spillway and the dam.
- In order to protect the channel bed against scour, the kinetic energy of the water should be dissipated before it is discharged into the d/s channel.
- Arrangements provided for energy dissipation are known as energy dissipators.
- For the dissipation of the excessive kinetic energy of water, the following two methods are commonly adopted.
 1. By developing a hydraulic jump
 2. By using different types of buckets

HYDRAULIC JUMP

- Hydraulic jump is the sudden rise of water that takes place when the flow changes from supercritical flow state to the subcritical state.
- When a stream of water moving with a high velocity and low depth strikes another stream of water moving with low velocity and high depth, a sudden rise in the surface of water place. This phenomenon is called hydraulic jump.
- This is generally accompanied by large scale turbulence, dissipating most of the kinetic energy of supercritical flow.

- It may be noted that the depth before the jump is always less than the depth after the jump.
- The depth before the jump is always less than the depth after the jump is called the initial depth (y_1) and the depth after the jump is called the sequent depth (y_2)



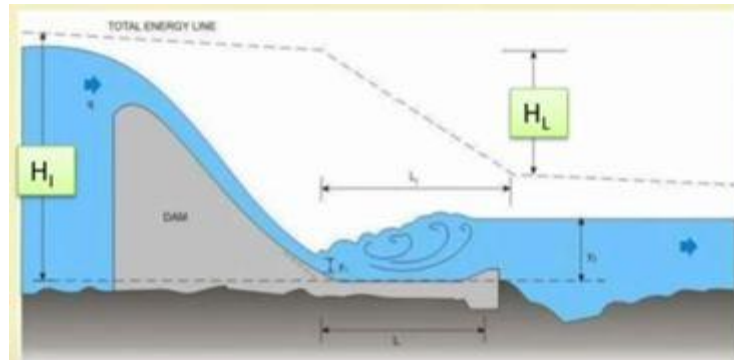
- In the specific energy diagram, the specific energy is minimum at point C. this depth of water in the channel, corresponding to the minimum specific energy (at point C) is known as critical depth.
- From the static energy curve, If $y = y_c$...critical flow
- If $y_1 < y_c$...supercritical flow If $y_2 > y_c$...subcritical flow

11. HYDRAULIC JUMP FORMATION

- For hydraulic jump to be developed in a horizontal rectangular channel, the following equation must be satisfied b/w pre-jump depth (y_1) and post-jump depth (y_2).

$$y_2 = -\frac{y_1}{2} + \sqrt{\frac{y_1^2}{4} + \frac{2q^2}{gy_1}}$$

- For a given discharge intensity over a spillway, the depth y_1 is equal to q/v_1 and v_1 is determined by the drop H_1 as $\sqrt{2gH_1}$.

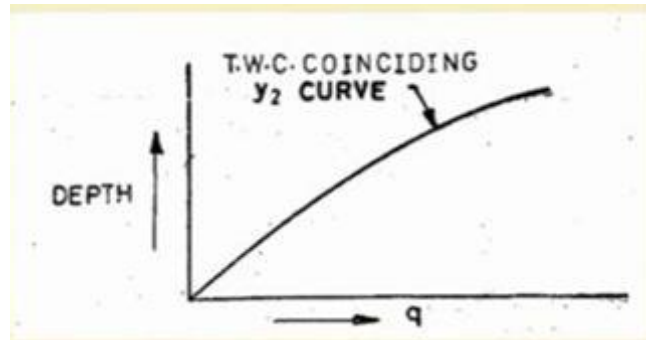


- Hydraulic jump formation depends considerably upon the Froude number of the incoming flow (F_1)
- The pre jump depth (y_1) and post jump depth (y_2) are governed by

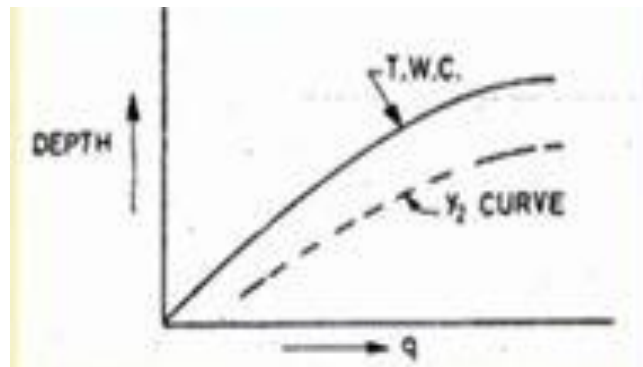
$$\frac{y_2}{y_1} = \frac{1}{2} \left[\sqrt{1 + 8F_1^2} - 1 \right]$$

Where $F_1 = \frac{V_1}{\sqrt{g \cdot y_1}}$

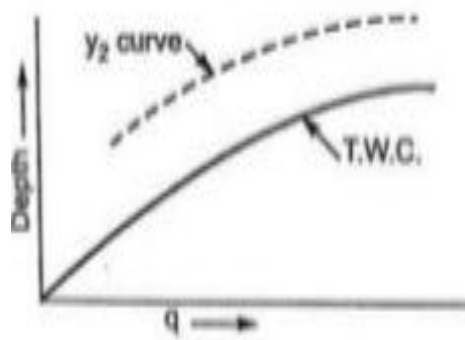
- If the incoming Froude number f_1 is higher, greater energy dissipation can take place
 - For a given intensity and given height of spillway, y_1 and y_2 are fixed.
 - Availability of a depth equal to y_2 in the channel on the downstream depends on the water level, which depends on the hydraulic dimensions and slope of the river channel below.
 - If a graph is plotted b/w q and tail water depth, the curve obtained is known as tail water curve (T.W.C).
 - If a curve is plotted on the same graph, between q and y_2 , the curve is known as the jump height curve (J.H.C) or y_2 curve.
 - If a graph is plotted b/w q and tail water depth, there are five possibilities
- a) T.W.C coinciding with y_2 curve at all discharges.



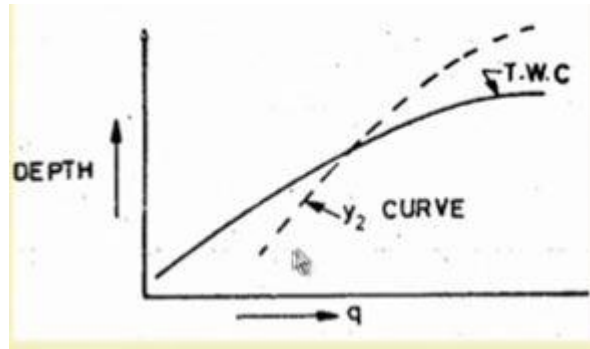
b) T.W.C lying above y₂ curve at all discharges



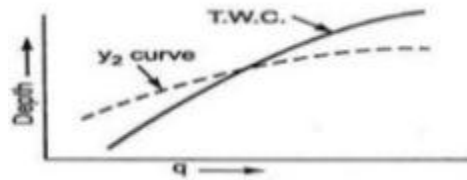
c) T.W.C lying below y₂ curve at all discharges



d) T.W.C lying above y₂ curve at smaller discharges and lying below y₂ curve at larger discharges.



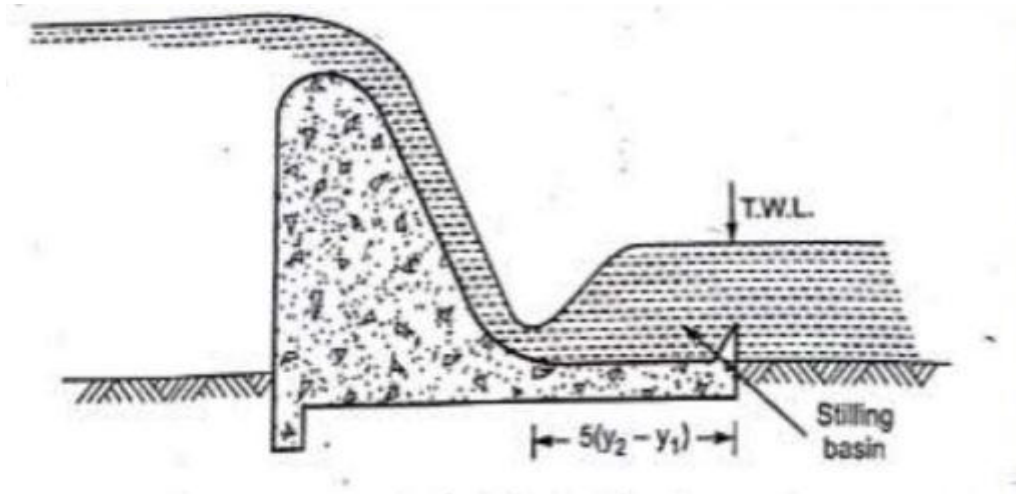
e) T.W.C lying below y_2 curve at smaller discharges and lying above y_2 curve at larger discharges.



Depending upon the relative position of T.W.C. And y_2 curve energy dissipation arrangement can be provided below the spillway as follow.

CASE A) T.W.C. Coinciding with y_2 curve at all discharges:

- This is most ideal Condition for jump formation
- The hydraulic jump will form at the toe of the spillway at all discharges
- In such cases, a simple concrete apron of length $5 (y_2 - y_1)$ is generally sufficient to provide protection in the region of hydraulic jump.

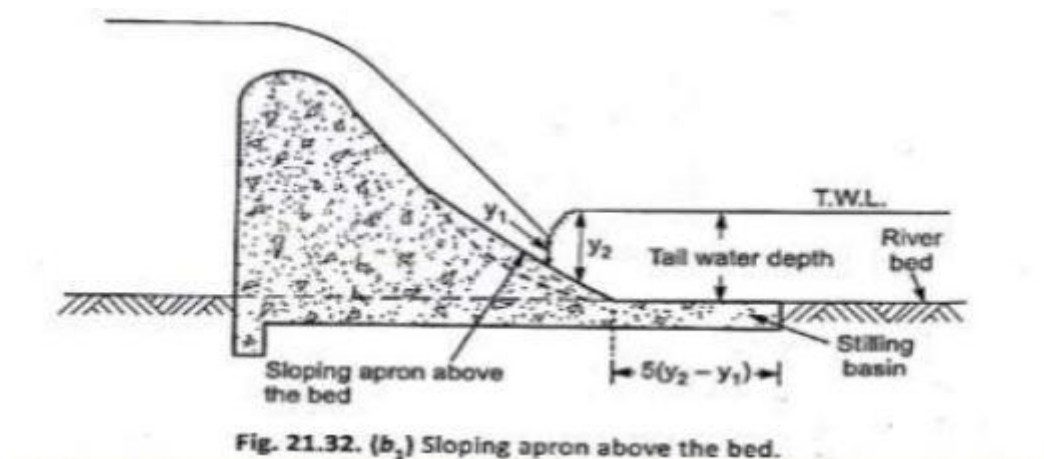


CASE B) T.W.C. Lying above the Y_2 curve at all discharges

In this case when y_2 is always below the tail water, the jump forming at toe will be drowned out by tail water, and little energy will be dissipated as follows:

i. By constructing a sloping apron above the river bed level.

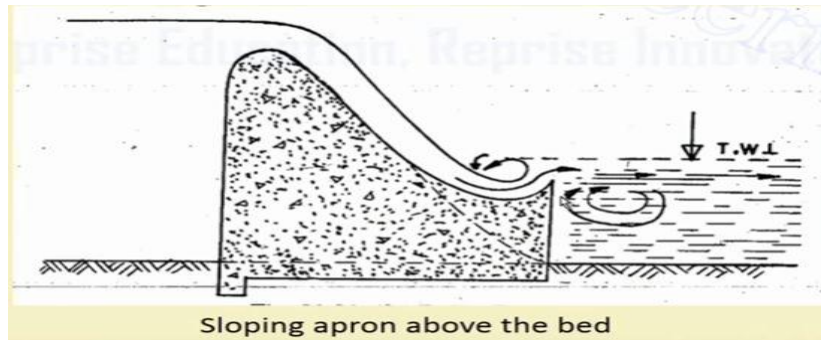
- Jump will form on the sloping apron where the depth equals to y_2 .
- Slope of apron is made in such a way that proper conditions for a jump will occur somewhere on the apron at all discharges.



ii. By providing a roller bucket type dissipators

- Roller which is formed d/s of the bucket, tends to move the scoured bed material towards the dam, thus preventing serious scour at toe of the dam

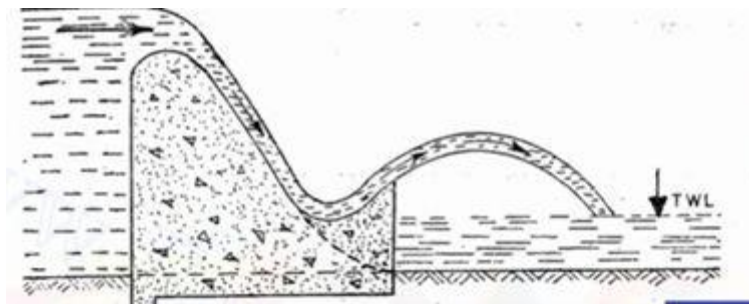
- Sometimes, the scoured material may enter the bucket under the action of u/s roller, and may cause severe abrasion.
- A dentated bucket lip may therefore have to be provided so as to permit removal of material caught in bucket



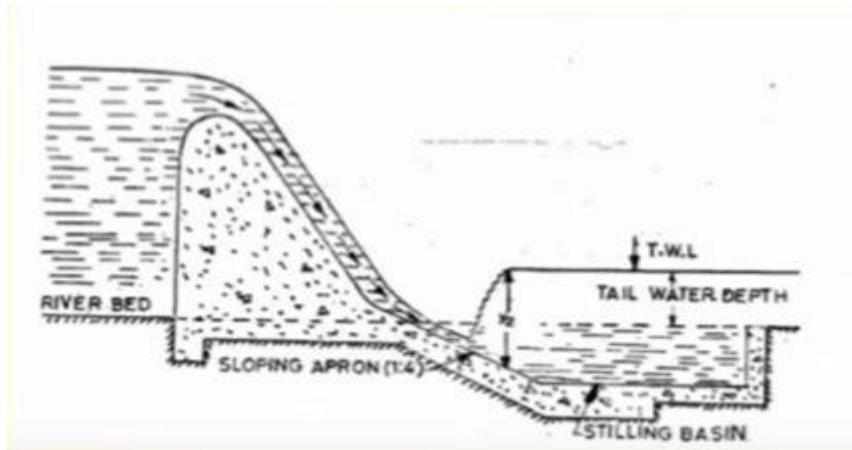
CASE C) T.W.C. lying below the Y_2 curve at all discharges

i) By providing ski jump bucket type dissipater

- If the tail water is very low, the water may shoot up out the bucket, and fall harmlessly into the river at some distance downstream of the bucket
- In such cases ski jump bucket energy dissipater is used

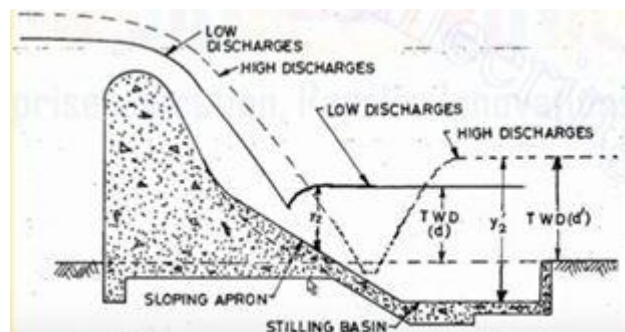


ii) By providing a sloping apron below the river bed



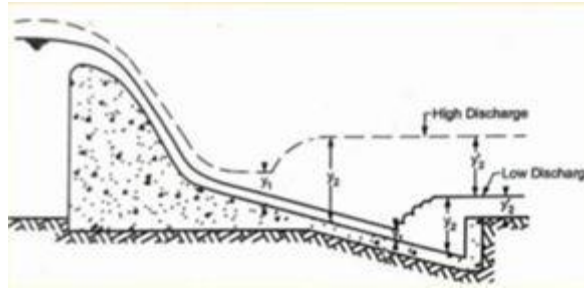
CASE D) T.W.C. Lying above the Y_2 curve at smaller discharges and lying below the Y_2 curve at large discharges:

- In this case, at low discharges the jump will be drowned and at high discharges tail water level is insufficient in such cases sloping apron partly above and partly below the river bed is provided.



CASE E) T.W.C. Lying below the Y_2 curve at smaller discharges and lying above the Y_2 curve at large discharges:

- This is the reverse of case (d)
- Same arrangement which was made in case (d) will serve the purpose
- Only difference will be that at low discharges, the jump will form on the apron below the bed; and at high discharges, jump will form on the apron above the bed



Energy dissipators below other types of spillways

- A chute or a shaft or a side channel spillway generally discharges at a point away from the dam
- Hence the protection is required only for the spillway, as the danger to the main dam is not there
- A hydraulic stilling basin is generally sufficient and may be provided at discharging point of spillway
- If sound rocks are available, a ski ump bucket may be provided at low cost